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16. ABSTRACT

A study was initiated in August, 1969, to attempt to learn more about the applicability of minicomputers (small, relatively inexpensive digital computers) to the field of traffic control. Present application of digital computers to traffic control is primarily restricted to attempts at controlling large blocks (100 or more) of intersections with one large digital computer. Since the advent of minicomputers, it appears there may be some advantages to their utilization for small groups of intersections (5 or less) or even single intersections. This study evaluates some of the potential applications of these minicomputers in the field of traffic control.

Conclusions and Recommendations:

The use of a minicomputer for traffic control research offers many advantages over conventional research tools. Most important of these, is relieving many of the present hardware restraints. A researcher could think in terms of how traffic should be controlled with the equipment presently available.

The use of minicomputers in lieu of present traffic controllers can be economical in many instances. The tremendous flexibility and capability advantages of the computer should be exploited. It is recommended that a trial computer controlled intersection be installed so that this concept may be evaluated under actual field operating conditions.

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APPLICATION OF A MINICOMPUTER TO TRAFFIC CONTROL

By Les Kubel and Les Miller

INTRODUCTION

A study was initiated in August, 1969, to attempt to learn more about the applicability of minicomputers (small, relatively inexpensive digital computers) to the field of traffic control. Present application of digital computers to traffic control is primarily restricted to attempts at controlling large blocks (100 or more) of intersections with one large digital computer. Since the advent of minicomputers, it appears there may be some advantages to their utilization for control of small groups of intersections (5 or less) or even single intersections. This study evaluates some of the potential applications of these minicomputers in the field of traffic control.

CONCLUSIONS AND RECOMMENDATIONS

The use of a minicomputer for traffic control research offers many advantages over conventional research tools. Most important of these, is relieving many of the present hardware restraints. A researcher could think in terms of how traffic should be controlled rather than how can traffic be most effectively controlled with the equipment presently available.

The use of minicomputers in lieu of present traffic controllers can be economical in many instances. The tremendous flexibility and capability advantages of the computer should be exploited. It is recommended that a trial computer controlled intersection be installed so that this concept may be evaluated under actual field operating conditions.

PROCEDURE

In order to examine the possibilities of using a general purpose computer as a traffic signal controller, several current controller types were simulated on a Hewlett Packard Model 2114A computer. This simply amounted to programming the computer to act like a controller. A "Type I" and a "Type II" controller were simulated both with and without pedestrian phases. Also, an eight phase loop occupancy controller was simulated. The limiting factor in deciding which controllers were to be simulated was never the computer. The most important factor for the purpose of this work was relative ease of demonstration. A Type III controller with variable gapping was considered but the involved nature of this controller does not lend itself to simple demonstration. The program for a Type III controller, however, appears to be a simple extension of the Type I program. Almost any characteristic which could reasonably be built in a hardwired controller could be handled by the 2114A. An attempt was made to write subprograms for the 2114A that would be useful for more sophisticated controllers.

After the programs were written and debugged, the "controllers" were demonstrated to members of the Division of Highways Traffic Department and discussions regarding the use of this concept were held. Cost and reliability comparisons with present traffic control equipment were made.

DISCUSSION

The particular 2114A used was equipped with a four thousand word memory. Each word contained 16 bits. This memory size proved quite adequate. The most sophisticated controller programs considered used about one thousand words of memory, and over a third of these were used for various control functions of the computer and would not be extended for more sophisticated controllers. The 2114A used was not equipped to handle automatic restart in case of power failure. This could be handled by a standard option available on most small computers.

The general purpose computer contains a generalized set of logic circuitry and a memory. The logic circuitry is capable of performing logical operations, arithmetic operations, comparisons, and input or output operations. The memory contains a list of instructions telling the logic circuitry what to do. In addition, the memory may also remember conditions or constants as required by the program. The general purpose computer can input timing pulses and actuations from detectors and based on these inputs, it can output signals to traffic lights.

Present day traffic control equipment contains a specialized set of logic circuitry designed to perform a specific task. This equipment remembers timing constants by virtue of adjustable front panel controls. To alter the inherent operational mode of this equipment generally means complete redesign of the logic circuitry. The computer, using generalized logic circuitry, can simply be reprogrammed to react in almost any operational mode desired.

A better understanding of the advantages of a computer can be obtained by looking at intersection control from a broader sense. From a mathematical sense, a controller is a time dependent multiport network; or if you prefer, a black box. The black box has a set of inputs from the detectors and a set of outputs to the traffic lights. Based on the condition of its inputs, the state of the box, and time, the box sets the outputs. The box makes its decisions by a detailed examination of the current conditions. If the box is in the proper state and if the proper detectors are actuated, and if the time is right, the outputs will change. In controlling a single intersection in a given manner, it makes little difference if the black box is a digital computer or a hardwired controller. Both are capable of making all of the necessary decisions. The advantages of the computer lie in the ease with which it can be re-educated to respond to a different criteria.

The black box must know the algorithm used to make the decision. In the case of the hardwired controller, the algorithm is left to the manufacturer. He decides what conditions will allow a change of state, and these conditions are built into the controller. If a change in operation is desired, the controller must be returned, redesigned, and rebuilt. Each change is a matter of adding circuits and rewiring the unit. These changes are expensive and time consuming. In the computer, however, the algorithm is its program. It is stored in its memory and it may be changed by reloading the memory. The reloading is accomplished by reading a punched tape with a teleprinter. This can be accomplished in a matter of minutes, and the entire operation of the black box can be changed. The same general purpose computer can be a pre-timed two phase controller or a traffic actuated eight phase controller with pedestrian phases. Most low cost general purpose computers available today are capable of several hundred thousand basic operations in a second. Processes far more complicated than those found in current traffic controllers are possible and, therefore, the general purpose computer could be used to try new ideas in traffic control without undergoing expensive hardware changes.

Programming the computer really involves little more than the first step in the construction of a hardwired controller. This step, in either case, is making a detailed step by step analysis of what must be done. Such an analysis will almost immediately translate into a computer program. From here the program is fed into the computer. In hardwired controllers, this is only the first step in a long process to produce a final controller.

Specifications and testing of computer systems would be easier since the hardware for all systems would be virtually identical. The only differences would be in the inputs or outputs or the size of the memory. "Software" computers are easier to test than their "hardwired" cousins. Special diagnostic programs are available which use the computer to check itself. By seeing what the computer does with the program, the technician can locate troubles in a short time. Since all of the computers are essentially the same, the technician does not have to worry about the special features required by a certain intersection. This could save a considerable amount of time.

Softwired computers hold a slight edge in reliability. The amount of electronic circuitry in the HP 2114A is approximately the same as that in an eight phase full actuated controller. This does not include the memory cores themselves, but these have been found to be virtually 100% reliable. The only known failures of memory cores have been mechanical failures, and they are considered very rugged. Using a computer with an eight bit word instead of the sixteen bit word in the 2114A should eliminate about 30% of the circuitry and cause a proportional increase in reliability. Additionally, the identical design of the computers should increase the reliability. Many of the failures in current hardwired controllers are caused by design errors. Softwired computers can be thoroughly tested for design errors.

From a physical standpoint the computer and current controllers are about the same size and consume comparable amounts of power.

Looking towards the future, the computer should have further gains. The next breakthrough in computer pricing should result from large scale integrated circuits. Large scale integrated circuits (LSI) are becoming available now and they should be quite economical in a very few years. By its nature, however, LSI is practical only where a large number of identical circuits are needed. Hardwired controllers are relatively low production items and the varied nature of each one does not make them suitable for LSI. Computers are produced in suitable quantities to make LSI very practical.

In the last few months, computers using read-only memory have become available. This memory can be used to store the program. These memories are cheaper and require less associated electronic circuitry. Programs are usually loaded by punching holes in plastic sheets. To be useful, the computer needs a small area of scratch pad memory in which it can both read and write. Large and medium scale integrated circuits are becoming available to fill this need. This memory will forget during a power fail but anything essential could be stored in the read-only memory. With the read-only memory, teleprinters would be unnecessary. Re-programming would be accomplished by changing the sheets. Some computers using this are available now for considerably less than $5000. As yet these machines are too small to be useful, but improvements will be forthcoming.

The general purpose computer has one other advantage. It could be interfaced with a recording device to record the traffic flow through the intersection. An incremental magnetic tape drive could be used, and the recording could be done simultaneously with the control. The tape recorded by the computer could be analyzed at the Division's Computer Center. Maximum and average waiting times as well as overall traffic flow could be computed. Special analysis of peak traffic periods would be possible.

There are some problems associated with the use of a general purpose computer for control of single or small groups of intersections. They are price, environment and man-machine interface.

The environmental problems may disappear in a few years at no added cost. The environmental problems now arise from both the memory and the integrated circuitry. Recent developments in memories have made possible low cost memories that will work over wide temperature ranges. Some of the most recent entries in the small computer market use these memories. The temperature range for integrated circuits has been increasing steadily for the past few years and this trend should continue. Improvements in quality control have already eliminated some of the very low range I.C's prevalent a few years ago. High range I.C.'s are available now at very little increase in cost and in a few years, high temperature I.C.'s may replace current low cost I.C.'s.

The price of small computers currently available makes them competitive with only the more complex signal control installations. A computer using four thousand words of eight bit memory should be adequate. Computer cycle time can be slow. Sophisticated hardware instruction sets are not necessary. Computers of this class are currently available with a base price of under $6000. Input and output interface must be supplied. A teleprinter and its interface would not be necessary at every installation. It is used only in the initial programming of the computer. This could save up to $2000 on an installation. With this reduction a computer system could cost between $8000 and $9000 complete with input and output interface.

Man machine interface to the computer is accomplished by means of programming. Most small computers utilize assembly language programs. Capable experienced assembly language programmers are not plentiful. Therefore, any significant utilization of this type of approach would probably require some programmer training effort. Maintenance training would also be required.

POTENTIAL APPLICATIONS

A small general purpose digital computer could be of significant use as a research tool. The extreme flexibility of this machine would allow a traffic researcher to free his mind of the equipment restraints. Almost any algorithm he chose to use to convert inputs into outputs could be implemented by programming. He would no longer have to scratch for equipment which would approximate a desired control concept.

More than one control concept could readily be tried at the same intersection and the results compared. If a suitable criteria for control effectiveness could be established and measured, recording could be made on magnetic tape and relative system effectiveness could be evaluated by computer.

Using the 2114A as a basis, a complete traffic control research system, with magnetic tape recording capability, might include the following:

HP 2114A with 4k memory	$ 9,950
Memory Parity Check (this option monitors the computer's operation)	1,000
Automatic Restart	500
Teleprinter and Interface	2,000
Microcircuit Interfacing (for input and output of data - 16 lines per board, 2 boards needed @ $750	1,500
Incremental Tape Drive and Interface	6,250
Additional Driver Circuitry to go between load switches, detectors and microcircuit interface boards -- estimated cost	600
	$21,800

In addition to this equipment, a complete controlling system would require detectors, load switches, failsafe monitoring flashers, and cabinet. The equipment should be suitable for field use except for temperature. Temperature restrictions on the computer and tape drive will require cooling the cabinet. Computers can be manufactured to meet the temperature range required but the cost for producing a small number of these could be very high, while the cost of air conditioning a trial system should be low.

The flexibility and capability of the general purpose computer may make it a practical controller for non-experimental purposes. The extreme flexibility of the computer allows it to be custom programmed to match truly unique intersections. This would make available traffic actuated control where previously this was difficult. Complete or partial overlap is simple, and unusual conflicting phases could be avoided. There is no real reason why non-conflicting phases should ever have to wait when a computer does the controlling.

Programming a computer for traffic control in special cases will remain difficult but almost any system currently covered by our Standard Specifications should be covered by a combination of standard subprograms. It is indeed quite conceivable that one of the computers in the computer section could be taught to program each individual case. A traffic engineer would describe the intersection in general terms to the computer and the computer would prepare the program. If desired, the program could be sent by standard teletype to the signal maintenance station in charge of the controller.

Where the economics of input-output communication between intersections permits, multiple intersections could be controlled from one computer. Each individual intersection could still be controlled independently, coordinated or both as desired.

The cost to replace a hardwired controller with a minimum computer is estimated as follows:

Basic Computer with K-8 Bit Memory	$ 5,000
Automatic Restart	500
Input-Output Interface	1,500
Additional Driver Circuitry	600
Memory Parity Check	1,000
Air Conditioning	300
Total	$ 8,900

Programming costs should also be included; however, they should become insignificant when prorated over numerous installations. The total estimated cost is roughly $1000 to $2000 higher than a full eight phase modular solid state hardwired controller. If multiple intersections in close proximity to each other were controlled by minicomputer, it is highly likely that the economic balance would swing to the side of the computer.

Softwired computers could prove much more economical in a few years. Aside from being more sophisticated and more capable, they can be changed easily to meet new demands. They should be compatible with whatever the future holds for traffic control.